User experienced dimensions in product design : a consolidation of what academic researchers know and what design practitioners do

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Experience has become the new paradigm of product design. Designers seek to anticipate emotions or associations a user might have when in contact with their design. The factors that influence human product perception are diverse. We firstly show which product dimensions are currently investigated by design researchers. It becomes obvious that besides the usual suspects: form and colour, emotion and associations, there must be many others. We conducted a study to identify these and to estimate their pertinence in actual product conception. Word-based techniques like retrospective verbalization and mind mapping were employed. Semantic descriptors, analogies, and functionalities were highly represented. Sensations and emotions did only appear marginally among the abstract dimensions. The same low occurrence was seen for production procedures among the concrete dimensions. Other interesting dimensions found were interaction gestures, design motifs, and product components. An additional analysis of the participant mind maps on relations between the various dimensions showed many connections between e.g. material and texture or semantics and colour. Yet, these were rarely related to sensations and emotions. The insights widen the perspective on unexploited opportunities for design researchers to develop further conception strategies that allow the anticipation of user experience in product design.

Keywords **-** product conception; product design; user experience

Relevance to Design Practice **-** This study introduces a wide range of dimensions which potentially impact the user experience but are only little regarded by designers. Practising designers can be stimulated to integrate more of the listed dimensions to enrich their concepts from the beginning of a new design task.

Introduction

Over the second half of the last century, a paradigm shift from a focus on product functions to the creation of meaningful products has taken place (Krippendorff, 2005). Today users expect more than well functioning products. Their interest can also be triggered by sensorial attributes, aesthetics or meaning. For example, Berluti shoes (Berluti, 2012) appeal through their precious leather finish, a cashmere pullover for its softness, the Sydney Opera through its pleasing proportions and the iPhone seduces with its notion of ubiquity. From these examples, we already see that different dimensions can stimulate the user. The artisanal quality of Berluti shoes becomes not only visible in the used materials but is also communicated through the classical forms and the brand image.

To describe this phenomenon, the term ‘experience’ is increasingly employed in the context of product conception. We read about “product experience” (Schifferstein, Hekkert, & et al., 2008), “experience design” (Hassenzahl, Eckoldt, & Thielsch, 2010) or “user experience” (Bruseberg & McDonagh, 2001; Garrett, 2010; Roto, Law, Vermeeren, & Hoonhout, 2010). The common goal is to conceive products that enrich the user experience of or with the product.

Our research focuses on the conception of products. The design conception phase is marked by a great amount of complexity and ill-structuredness (Simon, 1973). In order to support the designers, we seek to propose methods and tools that allow him to respond to the various shades of experience. To develop such tools, it is first of all necessary that we understand the totality of factors that influence the user perception of a product. This study therefore has for purpose to identify the wide range of experience related dimensions in product design.

In the first part of this paper, we highlight existing strategies for some of the well-investigated product dimensions like forms and colours. To prepare the ground for the study on conception dimensions, an overview on research methods for the analysis of concept contents is given. The main part is dedicated to the description of the study. We analysed concepts of industrial projects in order to see which dimensions appear in the considerations of professional designers and which could potentially enrich the design outcomes if considered more early in the product development. The findings and their impact on potential conception strategies are discussed in the final part.

Current activities on user experience dimensions

Products can be characterized by abstract attributes of higher order and concrete attributes of lower order (Snelders, 2003). Typical attributes that refer to the physic of products are attributes describing forms, colours, materials, textures, etc. We call them ‘concrete dimensions’. They are of objective nature and their conception follows common principles, for example the theory of Gestalt or rules of colour harmony established over the last centuries including theories of Goethe, Chevreul, Ostwald, Munsell, Itten, Moon and Spencer, etc. (Luo, 2006). For the choice of materials a wide range of online tools and sample banks is available (Ashby & Johnson, 2010; CES selector, 2012).

Yet attributes of product form, colour or material also carry a meaning. Their perception might provoke different emotions in each user (Crilly, Moultrie, & Clarkson, 2004; Desmet & Hekkert, 2007). We therefore refer to semantics, symbols, emotions and sensations as ‘abstract dimensions’.

To bring the abstract dimensions into a product, they have to be translated into concrete dimensions (Snelders, 2003). A growing number of researchers in the fields of “Kansei Design” and “Emotional Design” seek to understand their interplay. Since the 1970s, Kansei Engineers strive to relate forms, colours and textures with semantics. They employ the method of semantic differential questionnaires (Osgood, Suci, & Tannenbaum, 1957) in combination with physiological measurements (Levy, Nakamori, & Yamanaka, 2008). We find similar approaches for the relation of material with semantics and sensations (Karana, 2010) and textures with sensations (Akay & Henson, 2010). Besides the semantic differentials, a widely applied method to measure emotions – more precisely valence, arousal and dominance – are the manikins developed by Lang (Bradley & Lang, 1994). They found their way from psychology to design research and have been used for the evaluation of visual stimuli in form of product images or intermediate representations (Kim, 2011; Mantelet, Bouchard, & Aoussat, 2003). A similar instrument is the animated PrEmo character of Desmet which conveys an emotion through his caricatured facial expressions, gestures and sounds (Desmet, 2002).

Even though the abstract dimensions of products receive growing attention from designers and design researchers, the range of regarded attributes is still very limited. The methods of Kansei Engineering and Emotional Design mainly link emotions and semantics with visual stimuli like colours and forms. The dimensions materials and textures start to be subject of design research. Yet many further dimensions and their impact on the user experience remain to investigate.

Methods of concept contents analysis

The beforehand discussed research activities around product experience already revealed various important dimensions. We have also seen that only few of them have found their way into conception strategies. In this paper, we look into industrial projects to extract a holistic overview on represented abstract and concrete dimensions and their relations among each other.

One common means for researchers is observation. However since most parts of conception activities are of intrinsic nature, researchers need other tools to see what is going on in the minds of designers. Sketches, Renderings and CAD models are their main working tools. One can analyze these representations to draw conclusions on work contents. But it is in their nature to contain mainly information on forms and colours. Not all ideas can be visually represented but they may be expressed through words (Goldschmidt & Sever, 2011).

As we have seen before, colours and forms are by far the best implemented dimensions of product design. In order to avoid a focus on these two, verbal descriptions of the designers on their concepts seem a more neutral means to get a holistic view on designer concepts.

Segers, Vries and Achten believe that words deserve a more important role in design research.

They can contribute to the conception process as verbal expressions as well as in written format and serve to quickly externalize memory contents. Especially associations are often triggers for new ideas (Segers, Vries, & Achten, 2005).

Lawson and Loke argue “that creative design may be as dependent on words as it is on pictures”. Verbal descriptions leave room for interpretation which they consider suitable for the early conception phase (Lawson, Loke, & Tower, 1997). We adhere to their vision of a mental worded network which can illustrate concepts and the connections between ideas.

In order to access the contents treated by designers during a product conception, two word-based techniques have proven prolific in the fields of design and cognitive psychology: verbalization and mind mapping.

Verbalizations

Verbal reports of professionals allow researchers to access information related to their work contents. Someren et al. introduce different types of verbalizations.

1. Retrospective verbalization – done after the activity is finished. The participant recalls processes and contents from the long-term memory.

2. Introspection – done on multiple intermediate moments during the activity. The participant interrupts the activity and recalls the processes and contents from the working and long-term memory.

3. Concurrent verbalization (Think Aloud) – done in real-time during the execution of the activity. It reveals processes and contents directly from the working memory. There are no interruptions or suggestive prompts.

Retrospection holds the risk of information loss since only relevant aspects are recalled. Introspection allows for a nearly real-time account but the participants need to interrupt their actual activity. Concurrent verbalization give access to what happens exactly at the moment it happens but might disturb certain participants in their activity (Someren, Barnard, & Sandberg, 1994). Retrospective verbalizations and Think Aloud protocols have already been employed by various design researchers to whether analyse design processes (Gero & McNeill, 1998), cognitive activities (Kim, 2011) of the designer, or design contents (Suwa & Tversky, 1997).

Mind maps

Another way to gather conception words is through written accounts. The professionals note their thoughts on the problem at the moment when they occur. If written on separate papers the words can be positioned in relation to each other and create a mind map. Kokotovich showed that such mind maps are a highly efficient thinking tool in design. They allow visualizing the complexity of design dimensions to be handled and structured by the designer. Furthermore, they reveal relations between the dimensions which can lead the designer to his concept (Kokotovich, 2008).

Goldschmidt and Sever stated that designers easily relate lexical data to shapes, forms, and the relationships among them (Goldschmidt & Sever, 2011). Segers, Vries and Achten experimented with word-relations during architectural conception and saw their stimulating effect in the explorative design thinking phase (Segers, Vries, & Achten, 2005).

Study: An overview on concrete and abstract dimensions of product conception and their relations

The environment of the study

This study aims to analyze the multilayered contents of product conception in a real industrial setting. Product and graphic designers, as well as engineers in two European companies participated. One of them is an industrial design agency, the other a manufacturer of telecommunication devices. The design agency has experience in a wide range of sectors including sport, health care, automobile, distribution and communication. The designed products range from air pumps and pill dispenser, to portable gas bottles and garage doors. The manufacturer develops products for communication and divertissement like mobile phones, e-readers, tablet PCs and card reading devices.

A pre-study showed commonalities in the product development process of both companies. They undergo five subsequent phases: project initiation, problem analysis, conception, implementation, and follow up (Figure 1).

[Project initiation] Through a growing number of projects, the company refines its expertise and collaboration network. These lead to new assignments. If a potential project is identified, the conditions of the market and the industrial partners are being investigated.

[Problem analysis] Subsequently to a positive conclusion for the surrounding conditions, the company looks into the details of the competitive market and seeks to define the “added value” of the potential product for the end-user and/or a new business-model.

[Conception] In the following crucial conception phase different design directions are being explored. Certain ideas advance, others are abandoned. The marketing defines the target users, conducts a benchmark and estimates the potential revenues. The engineers choose the components and performance parameters which they expect to respond to the market requirements by the time of release. The designers are asked to propose a meaningful and ergonomic design for the future product. Together they define economic and ergonomic parameters, the product’s functionalities, use scenarios, the interplay with other products, etc. All these influence the product success. Functional and aesthetical properties have to be outbalanced through multiple iterations. The actions follow the steps of exploration, generation, evaluation, and communication (Cross, 2008).

[Implementation] Once the concept is decided on, the product enters the phase of implementation. Here problems of feasibility and financial constraints have to be resolved without too much deformation of the initial design concept.

[Follow up] Launched on the market, further adjustments are often necessary. These might concern technical amendments as well as visual brush-ups. The development of related equipment sometimes initiates a new project.

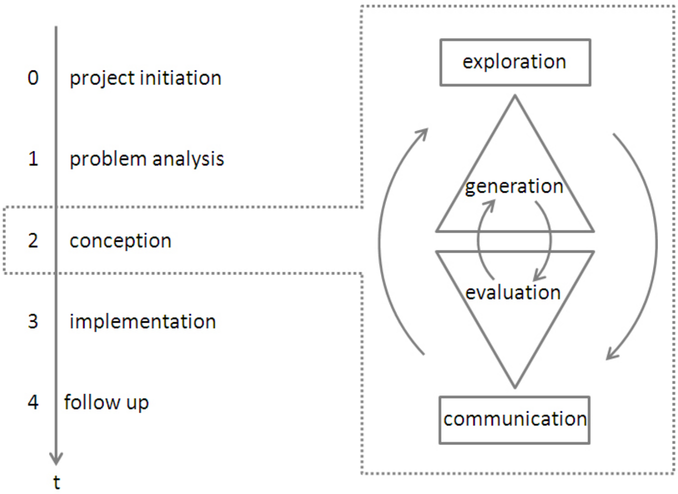

Figure 1. Product development process and

the stage of product conception adapted from Cross (right)

General approach

This study was divided into two phases. Firstly, we sought to confirm the hypothesis that concept words from verbalizations allow the extraction of abstract and concrete dimensions of designs. The participants verbally described the concept of one of their developed products. As a result a large base of conception words was gathered and categorized. In a second phase this word pool was enriched through a conception task. The professionals were asked to create a mind map for a fictive product brief. This also had for goal to illustrate which dimensions were related to each other.

Eleven professionals participated in this study, distributed as following: 5 product designers, 3 graphic designers and 3 engineers. They represented the whole conception team in their work environment. We chose a field research setting at their work place for the collection of data as unaltered as possible. Table 1 gives an overview of the two study phases, including their respective objectives and the adopted methods.

Table 1. The two phases of the study.

	Objective	Method	Participants
Phase 1	Extraction of a vocabulary for categorization of conception dimensions	Retrospective verbalization Post-it sorting	5 product designers 3 graphic designers 3 engineers

Phase 2	Extension of the vocabulary and extraction of relations between conception dimensions	Mind mapping

Phase 1: Extraction of a conception vocabulary for categorization of concrete and abstract dimensions

Objective and hypothesis

The pre-study showed the existence of a design process which integrates different stages of definition, evaluation and communication. These activities may be the source of relevant keywords describing the design specificities. We assumed that concepts can be described through words matching a limited set of dimensions. The goal was to identify a wide range of concrete and abstract dimensions treated by the designers and engineers during the product conception. Furthermore we also sought to compare the occurrence of each dimension between the different professions. We assumed that their expertise influences the dimensions regarded during a project.

Method

We employed the previously described technique of retrospective verbalization. We asked each professional individually to describe his/her conceived product and the processes that had lead to the outcome. They could bring visual supports (sketches, prototypes, etc.) to illustrate their narration. The verbalizations took about 30 minutes. No questions were asked by the two present researchers, expect for some stimulating enquiries. Along the verbalization, the researchers noted each key-word evoked by the participant on a separate post-it. As a second task, the participant was asked to sort his post-its into categories (Figure 2). We gave some examples for categories, like form, colour, sensation, etc. But they were also free to name their own categories.

Table 2 lists the projects which were subject of the study. All of them are real industrial demands which had been recently completed by the participants.

Table 2. Projects analyzed in phase 1 of the study.

Sector	*Product*
Sport	A light-weight bicycle air pump
Automobile	Graphics for a motorbike chassis
Cleaning	A detergent bottle
Distribution	A Portable gas bottle
	A logo for a gas distributing company
	An animation for gas distributor display

Handcraft	A home workshop tool
Communication	A portable home telephone
	A mobile phone (luxury brand)
	A mobile phone (sports brand)
	An e-reader

The experimentation was audio-recorded. The post-it sortings were photographed and reprocessed into Excel sheets. Based on the initial groups sorted by the participants, the two interviewing researchers and a third colleague unified the sortings into 18 categories. Each researcher would make a proposal for the categorization and for those with diverging opinions the decision was taken in group agreement and with consideration of the participant's discourse. Once all the words had been assigned to a dimension, statistical data on the word occurrence per dimension and per profession was available.

Figure 2. Sorting of concept words, phase 1.

Results: Categories of product conception dimensions

634 words were gathered during the first phase of the study. These could be categorized in the following 18 dimensions:

Table 3. List of conception dimensions, *definitions based on the Oxford dictionary.

	Aspect	Definition	Example
Concrete dimensions	Form	The visible contour	rounded, open, symmetrical
	Colour	The visual property of an object produced as a result of light reflection and emission*	green, red, golden
	Material	The matter from which a thing is made* or seems to be made off	polyamide, carbon, wood
	Texture	The appearance or consistency of a surface*	brilliant, craggy, smooth

	Patterns	A decorative image or design, a dominant or recurring idea*	arabesque, point, small squares
	Functionality	A technical solution to facilitate the expected function	geo-localisation, aeration, power supply
	Components	Means to implement the expected functionalities of the product	body housing, screen, battery
	Procedures	Procedures of fabrication and assembly	casting, injection, engraving
Abstract dimensions	Values	One's judgment of what is important in life*	liberty, sustainability, reliability
	Context	The circumstances that form the setting for an event*, like time, place, environment of the product use	morning, at home, rendezvous
	Target User	A person selected to use or operate the product	adolescent, early adopter, family
	Analogies	A comparison between one thing and another*, inspirations, conceptual references	like a water drop, dragonfly, magic lantern
	Semantics	Adjectives that describe the product, its meaning	dynamic, classic, feminine
	Sensations	A feeling resulting from something that comes into contact with the body* (sound, taste, smell, touch)	warm, soft, aromatic
	Emotions	A strong instinctive or intuitive feeling deriving from one's circumstances, mood, or relationships*	assuring, pleasant, funny
	Style	A way of painting, writing, composing, building, etc., characteristic of a particular period, place, person, or movement*	edge, retro-cool, pop-art
	Gestures	A movement of a part of the body, especially hand or head*, to interact with the product	touch, rotate, push, scroll
	Function	Practical use or purpose of a design*	communication, protection, leisure

Among the identified concrete dimensions are form, colour, material, texture and patterns. Furthermore we also found words related to technical functionalities and product components. Most participants mentioned some basic aspects of production.

The array of abstract dimensions ranges from values to semantic product descriptors, sensations and emotions, words that describe a specific style and analogies which transport a metaphoric idea. We also classed gestures of the user to interact with the product, words related to the expected macro function of the product, the use context and the target user under abstract dimensions.

This study phase showed that it is possible to extract a wide range of conception words from retrospective verbalization. Words belonging to various different concrete and abstract dimensions were employed by the participants and could be categorized. Subsequently, a second phase was added to increase the word base. The distribution of the words from phase one per dimension will be presented later in this paper together with the results of phase two.

Phase 2: Extension of the conception vocabulary and relations between concrete and abstract dimensions

Objective and hypothesis

The participants already suggested relations between the different conception words during study phase one. But these could not be exploited with the employed method. In phase two we sought to identify relations between conception words. We assumed that these relations build a systemic network which defines the product.

Method

Phase one was based on completed real design projects. These projects differed between the participants. The concepts were recalled retrospectively. In contrast, phase two was based on the fictive task: "Conceive a communicating coffee machine for Adidas". This brief contained familiar elements for all participants, while its slight unusualness provoked a disruption with their common work tasks.

The designers and engineers had one hour for the ideation. They were instructed to use the mind mapping method. After facing the brief, they were asked to write key-words of their thoughts on post-its. These post-its could be placed on a large paper surface. They could draw lines with markers to connect related words. The duplication or relocation of words was allowed. The participants were also animated to indicate relations of opposition. A list with the dimensions identified through phase one (similar to Table 3) had been introduced beforehand and placed in easy reach of the participants. They were also encouraged to share their thoughts (Think Aloud), so that the two observing researchers could follow their thoughts during the activity.

Following the individual conception, all participants (per company) post-its were united in a word pool and sorted by three researchers together into the dimensions of phase one. To sort ambiguous words (e.g. orange – as a colour or an analogy), the context from the simultaneous verbalizations was taken into account. The participants gathered and each was given a marker of a different colour. They had 45 minutes to pick words from the pool, position them on a wall surface, and mark relations of the newly placed words with already

Figure 3. Collective mind mapping, phase 2.

present ones. We encouraged a vivid discussion on the choice of relations among the participants. Everybody who agreed on a relation marked it with a line of his colour too.

The experimentation was videotaped. All produced mind maps were reprocessed into Adobe Illustrator images. A database was programmed in which all word pairs, marked through connecting lines, were inserted. The data base allowed us to quantify the distribution of links between dimensions. Dimensions which contained many words could evidently be more often involved in links. To overcome this effect, we normalized the data by dividing the absolute number of links between two dimensions by the product of words assigned to them.

$$\textit{normalized value} = \textit{number of links between two categories} \;/\; (\textit{number of words in category 1} \times \textit{number of words in category 2})$$

Result 1: Occurrence of concrete and abstract dimensions

513 conception words were collected during the second phase of the study. They could be partitioned into the 18 dimensions of phase one. 68 words of phase one reappeared in phase two (among them e.g. plastics, metal, black, touch screen, ecologic, dynamic, compact).

To estimate the significance of each of the conception dimensions and to compare their occurrence between different professions we combined the words of phase one and two. Table 4 shows the distribution of the collected words among the different concrete and abstract dimensions for each phase and their totality.

Table 4. Distribution of all words in the identified conception dimensions, for phase 1, phase 2, and total.

	Concrete dimensions								**Abstract dimensions**									
	Form	**Colour**	**Material**	**Texture**	**Patterns**	**Functionality**	**Components**	**Procedures**	**Values**	**Context**	**Target user**	**Analogies**	**Semantics**	**Sensations**	**Emotions**	**Style**	**Gestures**	**Functions**
Phase 1 - 634 words	10.3%	7.8%	4.1%	3.6%	1.1%	7.5%	10%	2.6%	10,1%	0	2.6%	13.8%	15.1%	0.3%	2.7%	0.3%	4.7%	3.7%
Phase 2 - 513 words	3.8%	2.6%	4.4%	3.6%	0.4%	18.2%	7.6%	3.2%	8%	6.8%	5.1%	12.4%	8.9%	4.1%	0.6%	1%	6.7%	2.6%
Total	7.3%	5.4%	4.2%	3.6%	0.8%	12.4%	8.9%	2.9%	9.1%	3.1%	3.7%	13.1%	12.3%	2%	1.7%	0.6%	5.6%	3.2%
	45.5%								**54,5%**									

If we compare the repartition between concrete and abstract dimensions, we find slightly more than half of all mentioned concept words under the abstract ones (54.5%). The consideration of both types of product dimensions was outbalanced. The dimensions with most conception words were analogies (13.1%) and semantic descriptors (12.3%) on the abstract side and functionalities (12.4%) on the concrete side. Style, sensations, and emotions on the abstract and procedures on the concrete side were the groups with the least number of words.

There is a difference in the word distribution between phase one and two. Phase one looked at completed products while phase two treated a fictive conception process. We see a similarly strong importance of conceptual references (analogies). The occurrence of words describing forms and components in phase one is inversed with the percentage of functionalities in phase two. For finished projects, functionalities appear in a relatively limited number while the precision on components is high. The semantic description appears more established on a completed product whereas the notion of context was relevant during the active conception of a new product in phase two.

Result 2: Differences between the professions

Almost all participants mentioned a few words for each dimension. However, the quantities of words per dimension differed between the professions. Table 5 presents the repartition of the concept words per dimension between product designers, graphic designers, and engineers.

Table 5. Distribution of words per dimension by profession, total of phase 1&2.

	Concrete dimensions								Abstract dimensions									
	Form	Colour	Material	Texture	Patterns	Functionality	Components	Procedures	Values	Context	Target user	Analogies	Semantics	Sensations	Emotions	Style	Gestures	Functions
Product designers	8.9%	3.9%	3.5%	4%	0.6%	12.6%	8.8%	3.5%	7.8%	4.6%	3%	13.4%	12%	2.2%	0.6%	0.9%	7.1%	2.7%
Graphic designers	7.2%	10%	2.2%	4.3%	2.2%	4%	4.8%	1.1%	9%	2.5%	3.2%	13.3%	16.1%	2.5%	1.5%	0.4%	2.5%	4.3%
Engineers	4.5%	5.4%	6.4%	2.6%	0.5%	15.3%	12%	2.8%	8.3%	1.9%	4.2%	13.9%	8.3%	1.9%	2.1%	0.5%	5.9%	3.5%

We see that semantic descriptors and analogies are among the most relevant conception dimensions throughout all professions. In contrast, functionalities appear strongly for product designers and engineers but much less for graphic designers. Engineers and product designers also take more components into account than graphic designers.

Result 3: Relations between concrete and abstract dimensions

The main objective of phase two was to investigate the relation between the different conception dimensions. Therefore the lines drawn between words on the mind maps were exploited. Figure 4 shows one product designer’s individual production, Figure 5 the collective map of the design agency’s members.

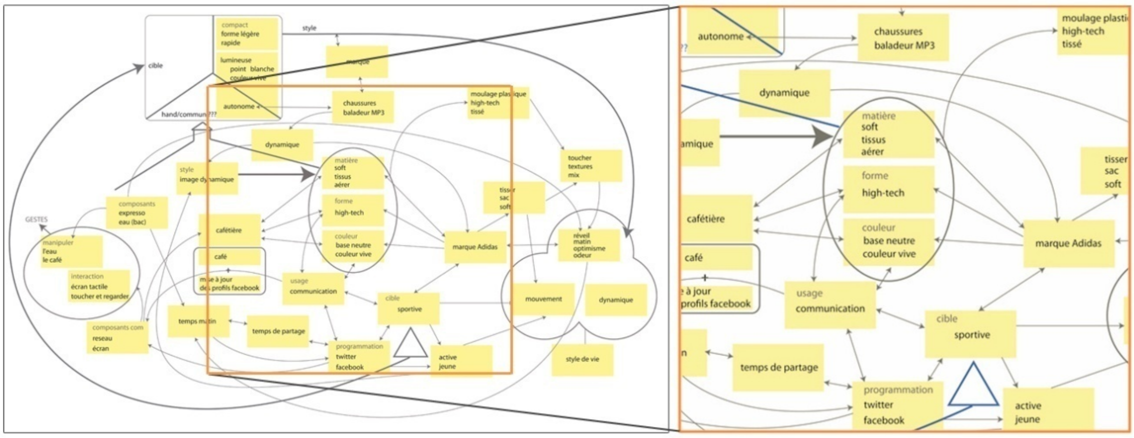

Figure 4. Example of the production of an individual mind map and zoom-in, phase 2.

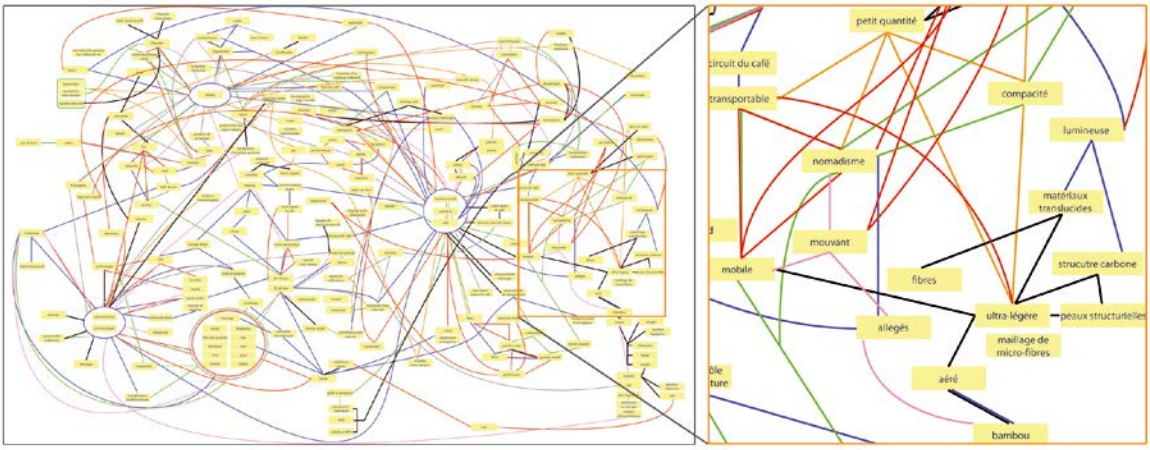

Figure 5. Example of the production of a collective mind map and zoom-in, phase 2.

During the individual exercise 861 links were drawn between the 513 words (an average of 78.3 links per person). During the collective activity the number of links was amplified to 1790 in total, which is equivalent to 174.5 links per person. Table 6 shows the normalized repartition of links between the words of two dimensions respectively.

Table 6. Normalized repartition of links between conception dimensions, phase 2.

	Form	Colour	Material	Texture	Pattern	Functionality /Function	Component	Procedure	value	Context	Target User	Analogy	Semantic Descriptor	Sensation	Emotion	Style	Gesture
Form	0.0385																
Colour	0.0595	0.0547															
Material	0.0113	0.0149	0.0476														
Texture	0.0152	0.0142	0.0390	0.0227													
Pattern			0.0159	0.0303													
Functionality	0.0034	0.0025	0.0011	0.0025	0.0027	0.0141											
Component	0.0083	0.0041	0.0083	0.0109		0.0099	0.0066										
Procedure	0.0048	0.0125	0.0071	0.0136		0.0088	0.0130	0.0175									
Value	0.0083	0.0078	0.0060	0.0011		0.0084	0.0027	0.0150	0.0244								
Context	0.0054	0.0018	0.0027	0.0026		0.0126	0.0031	0.0043	0.0243	0.0147							

Target User	0.0037		0.0037			0.0154	0.0025	0.0058	0.0135	0.0308	0.0651						
Analogy	0.0147	0.0064	0.0104	0.0070	0.0043	0.0160	0.0100	0.0058	0.0087	0.0103	0.0138	0.0095					
Semantic	0.0179	0.0026	0.0228	0.0246	0.0069	0.0100	0.0059	0.0115	0.0203	0.0113	0.0112	0.0118	0.0156				
Sensation		0.0024	0.0165	0.0035		0.0086	0.0042	0.0077	0.0077	0.0055	0.0030	0.0079	0.0072	0.0266			
Emotion		0.0156				0.0040	0.0109	0.0125				0.0064	0.0104	0.0385			
Style	0.0667	0.0750		0.0182		0.0016			0.0100			0.0154	0.0292				
Gesture	0.0093	0.0052	0.0013	0.0101		0.0091	0.0139	0.0097	0.0049	0.0056	0.0096	0.0053	0.0127	0.0096	0.0069		0.0262

We state the following connections:

- Intra-dimension links appeared frequently. We find strong relations inside the same dimension for colour, material, form and target user. The same applies on a slighter level for words belonging to texture, value, sensation and gesture.
- Between concrete dimensions, colour was often related to form. Material was often paired with texture. And pattern showed multiple links with texture.
- Between abstract dimensions, value was frequently related to semantic descriptors and words describing the use context. The context also appeared often together with terms on target user. Furthermore, emotion and sensation were often related.
- Strong links between concrete and abstract dimensions were formed between style and form as well as between style and colour. Furthermore semantic descriptors were frequently related to material and texture.
- Pattern, style and emotion were the groups with the least number of words and therefore, despite the normalization, the complete lack of links with some dimensions appeared.

In the created maps spatial proximity very often reflects a thematic connection. The grouping of ideas was done in the following ways:

1. words were placed in vertically descending lists,
2. words were placed close to each other,
3. connected ideas were encircled.

These word groupings contain three types of relations:

1. relations of linguistic similarity (e.g. stimulate, boost, energize),
2. relations of semantic proximity, (e.g. natural, Zen, bamboo),
3. affiliations to the same attribute (e.g. athlete, business man, coffee fan).

We found liaisons of

- convergence / hyperonymy (sport > jogging),
- divergence / hyponymy (soccer > sport),
- declinations on the same subject (sport > soccer, ski, jogging),

- associations between aspects (young athlete - fluid forms),
- relations of oppositions (relaxing - dynamic).

Even though the participants were explicitly encouraged to indicate links of opposition, we see very few relations of this type in the maps.

Result 4: Organization of conception knowledge

Beside the quantitative insights on conception aspects, which were the core of this study, the method employed in phase two unveiled different representation strategies among the participants. We observed three common phases in their strategies, while they arranged their words and lines on the work surface:

1. Positioning of the primal conception words: Initial key words were noted on post-its and placed on the surface. Some were already linked with lines. The more experimented participants produced more words than those with less experience at this first stage.
2. Addition of words: Words were added in relation to the initial words in a second phase. They occurred subsequently to a newly drawn link.
3. Repositioning of words: While the participants linked their concept words they also moved some of the post-its to facilitate the linkage and to group related terms spatially.

The chronology of the concept construction during the experimentation showed moments of spontaneous creation. Words flew out easily, were directly spatially organized and related. Other situations were more thought driven. The participant looked at the totality of the production from a distance and then reorganized the mind map. At the beginning, most participants preferred to first note and then group words before drawing linking lines. In the following two phases the links were usually drawn together with newly placed words. We saw that the observation of the mind map and creation of relations stimulated the participants when their ideas reached a point of exhaustion.

Discussion

Limitations of the results

The study allowed us to gather rich lexical data related to conception contents. These terms could be categorized into abstract and concrete dimensions. The obtained data showed tendencies in the occurrence of the various dimensions. However, the data is not representative in absolute values. If repeated on other projects the distribution will probably vary depending on the sector of the product and the expertise of the participant. Nevertheless the found proportions are likely to reoccur similarly. Our results are comparable to those our colleagues found in a previous study where they categorized information in early design stages. Here too functions, analogies, and semantics were the most cited dimensions (Kim et al., 2009).

We are conscious about the fact that the level of granularity between the identified dimensions

(Table 3) differs. Some of them are features, e.g. components or functionalities, while others are characterization of these features, e.g. colours or semantics (Hassenzahl, 2003). While colours, human values, or emotions represent a limited number of possible conditions (Kay, Berlin, Maffi, & Merrifield, 1997; Rokeach, 1973; Scherer, 2005), the number of semantic descriptors is merely infinite. Procedures and components could be further sub-categorized into fabrication, assembly, finishing, etc. Only their occurrence was too low to create relevant subcategories in this study.

If we compare the distribution of conception dimensions by profession, the result reflects the classic roles in terms of expertise and work field. The data also shows the overlapping interests between the professions. Product and graphic designers share considerations on form attributes and semantics. Product designers and engineers meet on aspects of functionality, components and analogies. Conception is a group activity in a multi-disciplinary work environment. This brings forth that engineers adopt the vocabulary of marketing and design and vice versa over the course of the product development. Semantics are essential for the communication of the concept inside the team and to the potential consumers. Another factor is the fluidity of professions over life time. We classed our participants by their current job description. But two of the participants came from engineering before working in product design. To separate the results by profession did therefore not bring relevant insights.

Limitations of the methods

Looking at the distribution of the dimensions, we noticed a difference between phase one and two. This is probably due to the real-time versus retrospective setting of the two tasks, more precisely the effect of the selective long-term memory mentioned before (Someren et al., 1994). Designers and engineers have memorized results of decisions that were made in the course of the project. Not everything envisioned during the conception process is remembered. The recall is probably more accurate for aspects that lead to actual features than for options that were not adopted. Future functionalities made up a great part of the mind mapping activity on the “communicating coffee machine for Adidas”. The participants sought to define the product purpose, before working on other dimensions.

Concerning the lack of links of contradiction in the participant’s mind maps, it must be assumed that such cannot be extracted with a technique like mind mapping. The method follows idea sequences – one idea makes appear the next one. This also corresponds to observations in one of our previous research projects (Westerman, Kaur, Mougenot, & Bouchard, 2007).

Perspective for product conception

We came across several classic industrial products in phase one of the study. This type of object seduces users with its performance and product design. We saw that concrete dimensions like form, colour, material, functionalities, and components had a prominent place in the conception activity. However, our results show a poor integration of production procedures in the early conception. We were also introduced to electronic products of divertissement that cannot be competitive through their product design only. To make them stand out, the product developers need to add innovative functions and engaging interactions. As confirmed by both companies, the conception of interaction and services has gained great importance for the success of their products. This is a field were abstract dimensions become crucial. As shown in the results, abstract dimensions like value, analogy, and semantic already appear in the consideration of the designers. But sensation and emotion of the future user were only little regarded.

Our main objective for phase two was to get insights into relations between the dimensions of product conception. The fact that intra-dimension links appeared frequently might be due to their contextual proximity. The other found links like between material and texture or style and form correspond overall to a common sense. They show that stakeholders of conception already hold the knowledge to estimate the consecutive consequences of choices on one aspect like material on others like colour, values or functionalities. They are able to undergo a quite holistic approach to product conception tasks, if stimulated accordingly.

The obtained data opens an interesting perspective for idea stimulation in early product conception. What products could be conceived if the stakeholders started the conception process with a consideration on relations between seemingly unrelated dimensions? For example how production procedures could be related to a sensorial experience? And how can contradictory aspects stimulate new product solutions as already applied in techniques like TRIZ (Shulyak, 1997).

Yet it is not only a question of stimulation. The mind maps (Figure 4 and Figure 5) illustrate the complexity of the knowledge that has to be accessed during the conception activity. The vastness of possible links seems already ungovernable by one person. Only a group of professionals can bring all necessary data together. Therefore, methods and tools that help identify and relate coherent and contradictory conception attributes are needed.

From a research method to a conception tool

The applied protocol during this study was intended for data gathering. However, we saw that the mind maps had a stimulating influence on certain participants. All attendees responded to the brief: “A communicating coffee machine for Adidas”. Here are two examples for the created concepts. Concept A) is a portable coffee machine module to be attached to a joggers arm. It communicates the exercise progress and transforms the emitted body heat into energy to be used for making a fresh coffee at the end of the morning run. Concept B) is a community coffee machine for a sport club around which club members gather and get latest sport news over a coffee.

Experimented designers advanced with ease and arrived at one or two clear concept directions during the one hour of mind mapping and linking. They used the provided list with concrete and abstract dimensions once their initial idea flow had stopped. The list brought new stimulation. We saw their excitement about all the dimensions that they had not yet integrated and that did further nourished their concept. The collective phase helped these participants to gain distance to their own production and to enrich their concept with the other participant’s ideas. Two senior product designers gave positive feedback about this word-based method after the study was completed.

Senior product designer 1:

> The words are a good start base. This helps to not overcharge the concept while defining the project perimeters. When one limits himself to […] just a few words, one can focus on the concept. When you draw, you have to combine a lot of things immediately.

Senior product designer 2:

> The list [with the conception dimensions] did not really change my approach but it allowed me to add little things forgotten otherwise. Habitually, the implementation [the production procedures] arrives a bit later. One defines the form, justifies this form and the texture and then chooses casting and plastic. This [the experimented method] seems very coherent to me and helps to define a maximum. […] this helps to find a more in depth answer than I would get, if I started directly with sketches for searching a solution. Generally, when one searches, one makes sketches of the product to see the consequence directly. For a task that seemed a bit absurd at the beginning, with looking for links one sees that one can actually propose something like that. It helps to deepen his reflection.

Novices used the list right away and worked it down. This also seems to have worked since in the end all of them reach a few different product ideas. But in comparison with the senior designers, they did not build one coherent idea in the course of the available hour. Two of the engineers had difficulties with the method. They defined various product constraints but did not reach a concept. They said the task was not authentic enough.

With this in mind, we state that a word-based mind map with support of a list of conception dimensions can be a useful tool for experienced designers. It may stimulate the divergence of their ideas and help them to generate a holistic product concept. However it has limitations for novices or engineers who tend to converge quickly. These findings are complementary with those of Kokotovich who had found that mind maps are a useful tool for students since they prevent a too early embodiment of ideas and leave more space for creative connections (Kokotovich, 2008).

A scheme on human-product interaction

In the introduction we already mentioned that we see concrete dimensions materialized in the product and abstract dimensions strongly related to the human perception. We also stated interdependency between these two.

Following the insights of this study we propose a simple scheme of the user-product-interaction situation (Figure 6). In accord with other researcher's frameworks, we placed the user on one side, the product on the other side. The interaction cycles between the two (Crilly, Moultrie, & Clarkson, 2004; Forlizzi & Ford, 2000; Locher, Overbeeke, & Wensveen, 2009).

The interaction is triggered by different concrete dimensions of the materialized artefact, e.g. the form and the colour (Bonnardel, Piolat, & Le, 2011). Parts of this stimulus reach the sensors of the user. Only relevant stimulus information will enter the perception circuit. The relevance depends on the context as well as temporal or spatial changes in the stimulus (Gibson, 1986). The received information is treated through comparison with memory contents and potentially causes an affective response that might lead to a motoric response. For instance, the particular form of the product raises the user’s curiosity. He reaches out to touch the object.

The object now senses certain characteristics of the user response, for example the change of pressure on its surface. Depending on its capabilities, it responds by changing its form. The user senses this new stimulus, the deformation, through the tactile sensors of his hands. This again might stimulate him to try other gestural responses. This cycle is called the “sensorimotor coupling” within the enaction approach (Lenay, 2006).

We positioned the identified concrete and abstract dimensions in this cycle. All concrete dimensions that potentially form the stimuli for the user have been mapped under the product response. They include characteristics of form, colour, material, texture, as well as the functions, and product components. For externally perceivable components the modes of fabrication and joining are also considered as potential stimuli. Response needs to be understood as a wide term that includes appearance as well as behaviour.

Sensations describe the information that is captured by the human sensors (visual, audible, tactile, gustative, and olfactive). Emotions are related to the affective part of perception. In the context of products these are usually limited to degrees of attractiveness, pleasantness, satisfaction, or surprise (Crilly, Moultrie, & Clarkson, 2004). Values are part of the cognition on the human side. The user gestures or facial expressions are positioned among the motoric responses of the human.

It is difficult to place semantics, analogies, and symbols. On the one hand they are part of the user cognition, but before that they have been manifested in the product design following the designer's intention.

While the abstract dimensions experienced with one product might differ between each user, the perception of the concrete dimensions is more or less consistent, except in case of cognitive or physical limitations. The abstract dimensions form the objective of product conception. Thereafter the design materializes this design objective through the concrete dimensions. A product experience is generated through the interplay of abstract and concrete dimensions in a specific context.

Norman reminds us that experience is not static but changes with time. The first cycle in our scheme corresponds to the perception on his so-called “visceral level”, while further sensorimotor cycles add an experience on the “behavioural level”. Even when the product has disappeared from sight, the memory of it can still trigger emotions on the “reflective level” (Norman, 2004).

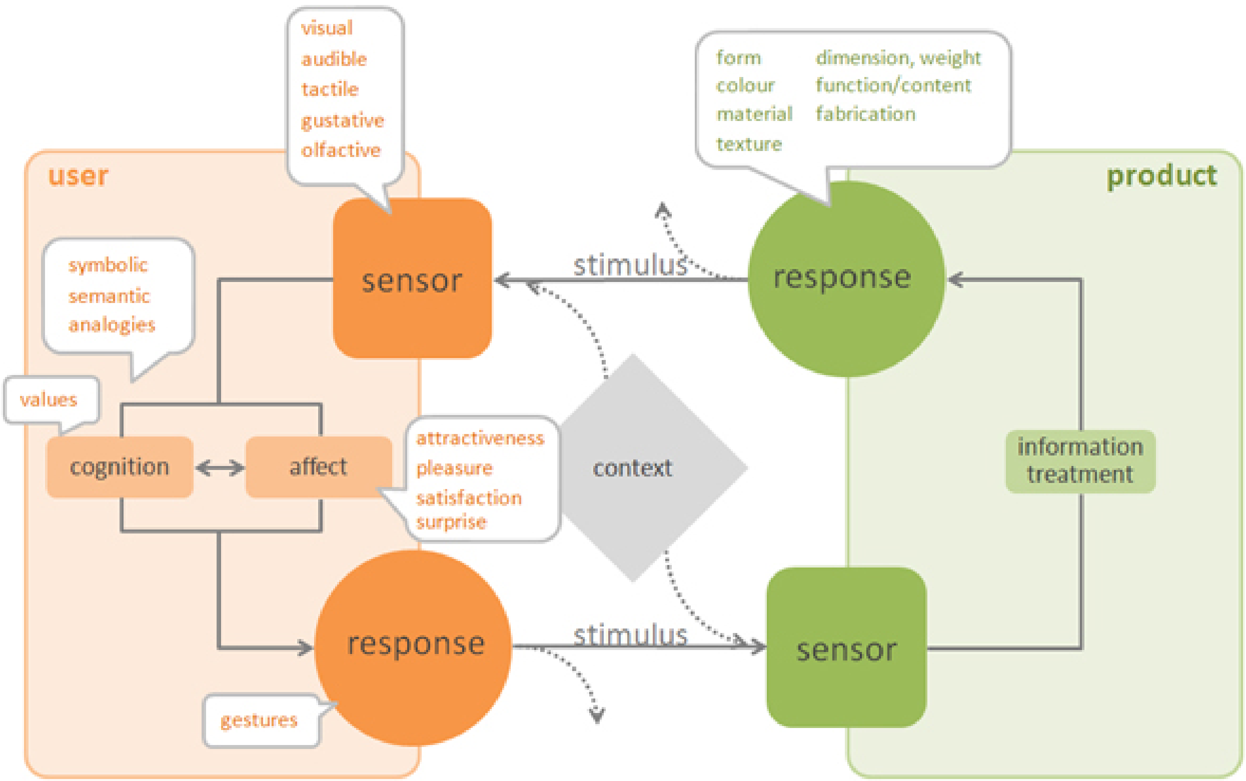

Figure 6: Scheme of the user-product interaction cycle

Conclusion

The presented study broadened our scope on concrete and abstract dimensions that play a part in user experience. We first looked at completed industrial products and then assigned a fictive conception task to professional designers and engineers to investigate which contents they treated during the design process. The applied methods were word-based. The first part on completed projects was done through retrospective verbalizations, the second part with mind maps on a fictive design problem. Various concrete dimensions, among them form, colour, material, texture, functionality, product component, and production procedure appeared in the considerations of the participants. Furthermore, the perspective of the potential user was taken into account through abstract dimensions like value, the use context, analogy, semantic, emotion and sensation. Functionality, analogy and semantic occurred much more often than production procedure, emotion and sensation.

Through analysis of relations between concrete and abstract dimensions, indicated by the participants through lines on the mind maps, we saw that classical product design characteristics like form, colour, material and style were often linked among each other. However, links with emotions and sensations were very few. Relations between abstract dimensions were not much exploited either.

The manifoldness of the compiled data reflects the complexity of product conception tasks. To handle the whole spectrum of dimensions that potentially influence the user experience, designers need supporting strategies. We hope the study insights motivate practising designers to consider a wider range of factors from the beginning of a new design task. The findings should also encourage the design research community to pursue the development of conception methods and tools that help designers to integrate a wider range of abstract and concrete dimensions from the early conception onwards. Following this study, we intend to refine the distinction of the found dimensions with regard to factors of human-product-interaction, specifically dimensions of behaviour as part of human and product responses.

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References

1. Akay, D., & Henson B. (2010). Predicting affective properties of tactile textures using ANFIS. In *Proceedings of the International Conference on Kansei Engineering and Emotion Research*. Paris.
2. Ashby, M., & Johnson K. (2010). *Materials and Design* (2nd ed.). Butterworth-Heinemann.
3. *Berluti* (n.d.). Retrieved July 27th, 2012, from http://www.berluti.com/.
4. Bonnardel, N., Piolat, A., & Le, L. (2011). The impact of colour on Website appeal and users ’cognitive processes’. *Displays, 32*(2), 69-80.
5. Bradley, M. M., & Lang, P.J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*(1), 49-59.
6. Bruseberg, A., & McDonagh, D. (2001). New product development by eliciting user experience and aspirations. *International Journal of Human-Computer Studies, 55*(4), 435-452.
7. *CES Selector* (n.d.). Retrieved July 27th, 2012, from http://www.grantadesign.com/products/ces/.
8. Crilly, N., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: consumer response to the visual domain in product design. *Design Studies, 25*(6), 547-577.
9. Cross, N. (2008). *Engineering Design Methods*. Chichester: John Wiley & Sons Ltd.
10. Desmet, P. (2002). *Designing Emotions*. Unpublished doctoral dissertation, TU Delft, Delft, Netherlands.
11. Desmet, P., & Hekkert, P. (2007). Framework of Product Experience. *International Journal*

of Design, *1*: 57-66.

12. Forlizzi, J., & Ford, S. (2000). The Building Blocks of Experience: An Early Framework for Interaction Designers. In *Proceedings of Symposium on Designing Interactive Systems*, (419-423). New York, NY.

13. Garrett, J. J. (2010). *The elements of user experience* (2nd ed.). Berkeley: New Riders Press.

14. Gero, J. S., & McNeill, T. (1998). An Approach to the Analysis of Design Protocols. *Design Studies*, *19*(1), 21-61.

15. Gibson, J. J. (1986). *The Ecological Approach to Visual Perception*. New York, New York, USA: Psychology Press.

16. Goldschmidt, G., & Sever, A. L. (2011). Inspiring design ideas with texts. *Design Studies*, *32*(2), 139-155.

17. Hassenzahl, M. (2003). The Thing and I: Understanding the Relationship Between User and Product. In Blythe, M. A., Monk, A. F., Overbeeke, K., & Wright, P. C. (Eds.), *Funology: From Usability to Enjoyment* (pp. 31-42). Dordrecht: Kluwer Academic Publishers.

18. Hassenzahl, M., Eckoldt, K. & Thielsch, M. T. (2009). User Experience und Experience Design - Konzepte und Herausforderungen. In Brau, H. (Eds.), *Usability Professionals 2009. Berichtband des siebten Workshops des German Chapters der Usability Professionals Association e.V.* (pp. 233 - 237). Stuttgart: Fraunhofer-Verlag.

19. Karana, E. (2010). *Meanings of Materials*. LAP Lambert Academic Publishing GmbH.

20. Kay, P., Berlin, B., Maffi, L., & Merrifield, W. (1997). Color Naming Across Languages. In Hardin C.L., & Maffi, L. (Eds.), *Color Categories in Thought and Language*, (pp. 21-56). Cambridge University Press.

21. Kim, J. (2011). *Modeling cognitive and affective processes of designers in the early stages of design: Mental categorization of information processing*. Unpublished doctoral dissertation, Arts & Métiers ParisTech, Paris, France.

22. Kim, J., Bouchard, C., Omhover, J.F., Aoussat, A., Moscardini, L., Chevalier, A., Tijus, C., & Buron, F. (2009). A Study on Designer's Mental Process of Information Categorization in the Early Stages of Design. In Proceedings of *International Association of Societies of Design Research*. Seoul.

23. Kokotovich, V. (2008). Problem analysis and thinking tools: an empirical study of non-hierarchical mind mapping. *Design Studies*, *29*(1), 49-69.

24. Krippendorff, K. (2005). The semantic turn: A new foundation for design. Boca Raton, FL: CRC Press.

25. Lawson, B., Loke, S. M., & Tower, A. (1997). Computers, words and pictures. *Design Studies*, *18*(2), 171-183.

26. Lenay, C. (2006). Enaction, Externalisme et Suppléance Perceptive. *Intellectica, 1*(43): 27-52.

27. Levy, P., Nakamori, S. & Yamanaka, T. (2008). Explaining Kansei Design Studies. In *Proceedings of Design and Emotion*. Hong Kong.

28. Locher, P., Overbeeke, K., & Wensveen, S. (2009). A Framework for Aesthetic Experience. In *Proceedings of Conference on Human Factors in Computing Systems*. Boston.

29. Luo, M. (2006). Applying colour science in colour design. *Optics & Laser Technology, 38,* 392-398.

30. Mantelet, F., Bouchard, C., & Aoussat, A. (2003). Integration and optimization of KANSEI engineering in the process of design of new products. In *Proceedings of the 6th Asian Design Conference.* Tsukuba.

31. Norman, D. A. (2004). *Emotional Design*. Cambridge, MA: Basic Books.

32. Osgood, C. E., SUCI, G. J., & Tannenbaum, P. H. (1957). *The measurement of meaning*. University of Illinois Press.

33. Rokeach, M. (1973). *The Nature of Human Values.* New York, New York, USA: Free press.

34. Roto, V., Law, E., Vermeeren, A., & Hoonhout, J. (2010). User experience white paper. *Dagstuhl Seminar on Demarcating User Experience*. Dagstuhl.

35. Scherer, K. R. (2005). What are emotions? And how can they be measured? *Social Science Information, 44*(4), 695-729.

36. Schifferstein, H. N. J., Hekkert, P. (2008). *Product Experience* (1st ed.). Elsevier Science.

37. Segers, N.M., Vries, B. de, & Achten, H. H. (2005). Do word graphs stimulate design? *Design Studies, 26*(6), 625-647.

38. Shulyak, L. (1998). Introduction to TRIZ. In Altshuller, G. (Ed.). *40 Principles: TRIZ Keys to Technical Innovation.*(pp. 15-22). Worcester: Technical Innovation Center.

39. Simon, H. A. (1973). The Structure of Ill Structured Problems. *Artificial Intelligence,* (4), 181-201.

40. Snelders, D. (2003). An exploratory study of the relation between concrete and abstract product attributes. *Journal of Economic Psychology, 25*, 803-820.

41. Someren, M. W. van, Barnard, Y. F., & Sandberg, J. A. C. (1994). *The think aloud method - A practical guide to modelling cognitive processes*. London: Academic Press.

42. Suwa, M., & Tversky, B. (1997). What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies, 18*(4), 385-403.

43. Westerman, S., Kaur, S., Mougenot, C., & Bouchard, C. (2007*). Trends Meta deliverable 2 - user factors.* Retrieved July 31, 2012, from

http://www.trendsproject.org/files/deliverables/TRENDS Meta-deliverable 2 - User factors.pdf.